

# Voyager Bulletin

MISSION STATUS REPORT NO. 67 OCTOBER 12, 1981

## Update

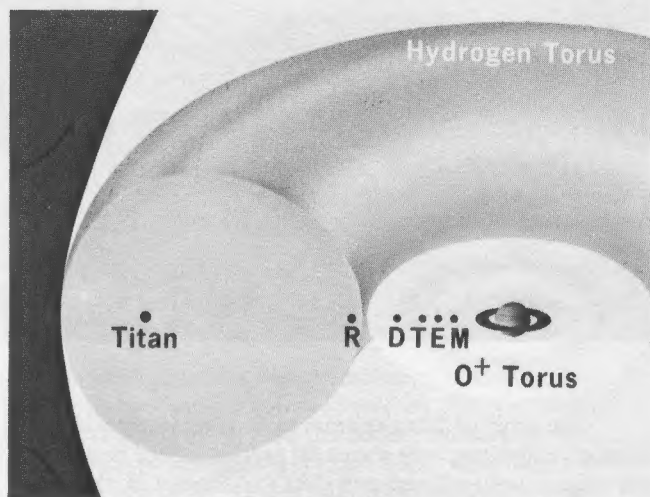
Voyager 2 has completed nearly half of its journey to Uranus, measured from launch on August 20, 1977 to Uranus closest approach on January 24, 1986. The four-year-old spacecraft, having travelled 2.4 billion kilometers (1.5 billion miles) continues to operate well. Analysis continues on its scan platform, which stuck shortly after closest approach to Saturn on August 25. The platform has been successfully maneuvered since then and prospects for a successful Uranus encounter are good. The problem appears to be related to lubrication, worn gear mechanisms, and close clearances between gears in the platform's azimuth actuator.

Voyager 1 continues to explore interplanetary space, having travelled over 2.7 billion kilometers (1.7 billion miles) since its launch on September 5, 1977. Voyager 1 hiccupped a little last week and presented flight controllers with an interesting computer glitch. The problem occurred on October 6 as controllers were changing the cruise data modes in one of six reprogrammable computers aboard the spacecraft. The flight data subsystem (FDS) computer program appeared to be stuck in a tight loop, ignoring commands from the computer command subsystem (CCS). An early effort to implement a new configuration command failed, but flight controllers were able to send "power on reset" commands on October 7, causing the FDS program to reset, and good data has been received since then. Two possible causes of the problem are being explored. The CCS may have sent a garbled command to the FDS, causing the FDS to begin sending meaningless data. The command would have been issued from the same CCS output unit that has caused several other problems aboard Voyager 1 since launch, including a maneuver abort. Another possibility is a failure of several words of FDS memory. Analysis of the problem continues.

## Saturn Science Results

### The Magnetosphere

Voyager 2's trajectory took it on a wide arc through Saturn's magnetic field, exploring different regions and adding to the data of Pioneer 11 and Voyager 1.



Saturn and its satellites are surrounded by clouds of rarefied gases which form donut-shaped rings. A torus of neutral hydrogen extends from the magnetosheath at about 25 Saturn radii inward to about 7.5 Saturn radii (Saturn's radius is 60,330 km). Titan's atmosphere is believed to be the source of hydrogen in this torus. Nestled between the hydrogen torus and the planet is a smaller torus of ionized oxygen, believed to escape from Tethys and Dione. This torus extends from the inner edge of the hydrogen torus to about the orbit of Enceladus at about 3.9 Saturn radii. Its mass is about 40,000 tons, compared to 2 million tons for Jupiter's Io sulfur torus.

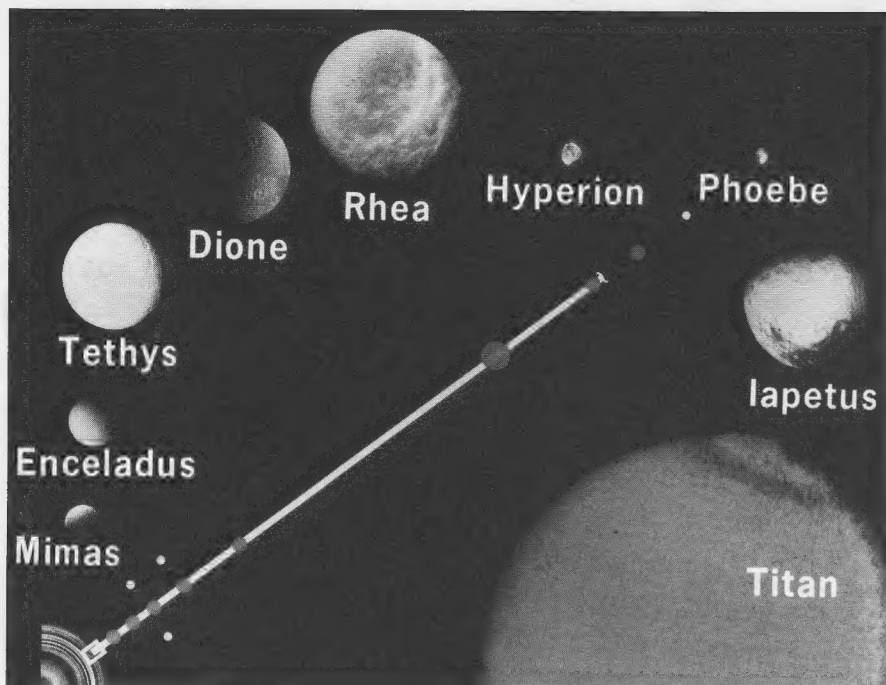
All planets which have internally-originating magnetic fields also have magnetospheres. Magnetic field lines extending from pole to pole form a series of "shells" which rotate with the planet, sweeping charged particles around as well. When particles streaming from the sun in the solar wind meet the boundary of a planet's magnetic field, a bow shock occurs. Most of the solar particles are deflected and stream around the magnetosphere. Behind the bow shock, there is a region called the magnetosheath where particles stream at subsonic speeds. Finally, the magnetopause is the actual boundary between the magnetosheath and the magnetosphere. A magnetic tail is formed as solar wind particles stream past the planet and regroup. This magnetic tail may be of hundreds of millions of kilometers long at Saturn. Jupiter's magnetic tail may be half a billion miles long, extending as far as Saturn and blowing in the solar wind like a tattered wind sock.

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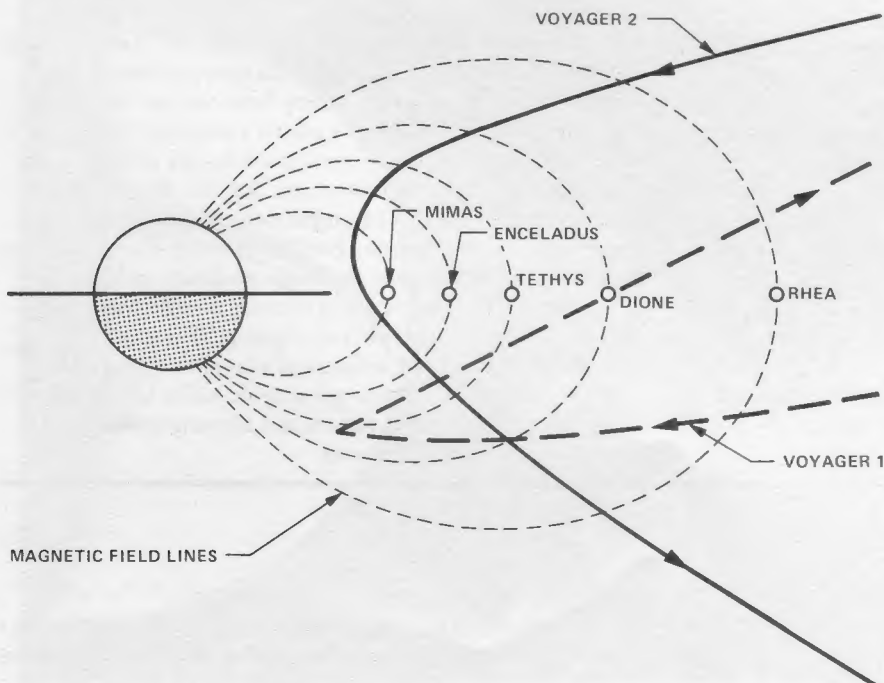
Some of the Voyagers' best resolution images of Saturn's larger satellites are shown in this composite. The diagonal line references the satellites' distances from Saturn to scale. The box drawn over the rings indicates the area where most of the small satellites are found. Moving outward from the planet, the satellites are Mimas, Enceladus, Tethys with its two companions, Dione with its small orbit-sharer, Rhea, immense Titan, and Hyperion. The line break indicates a break in the scale since Iapetus and Phoebe orbit at great distances beyond the other satellites. The satellites fall into three general classes: the tiny "rocks", the medium-sized icy satellites, and planet-sized Titan. The dark polar band in Titan's atmosphere can be seen in this image.

The orbit of Titan appears to be completely within Saturn's magnetosphere about 80 percent of the time, as the magnetosphere boundary ebbs and flows with the changing solar pressure. The interaction of the satellites with the magnetosphere is a prime area of study for the Voyagers. As the inner satellites orbit the planet, they clear a path through the charged particles in the magnetosphere and leave a wake much like a motor boat leaves. Like the motor boat's wake, the disturbance gradually quiets and returns to normal until the satellite comes around again. In addition, the satellites absorb charged particles as they spiral down Saturn's magnetic field lines. Measurements taken below the plane of the satellites show fewer protons in the satellites' "shadows". At Mimas, measurements of both the wake and the shadow indicate

that another small body may be sharing the orbit.

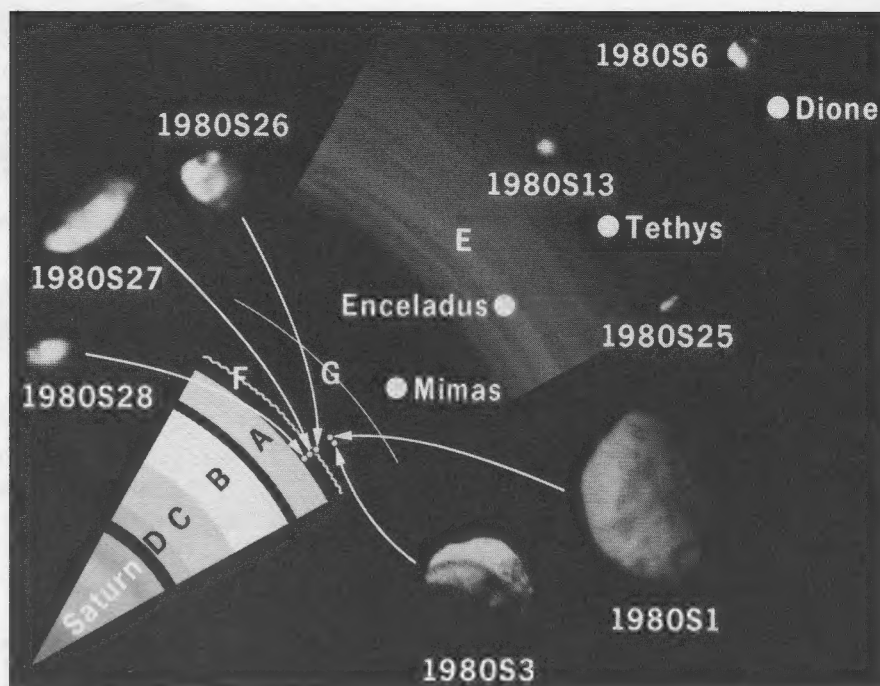
Saturn is surrounded by two donut-shaped clouds of gases. The inner cloud (or torus) is comprised of ionized oxygen which is believed to originate from the icy satellites Tethys and Dione. The mass of the oxygen torus is one-fiftieth that of the Io sulfur torus at Jupiter. Io's volcanoes supply material to the torus at the rate of one ton per second; Tethys and Dione supply material at the rate of about one pound per second.

The oxygen torus extends to about halfway between the orbits of Dione and Rhea, where it meets the inner edge of a neutral hydrogen torus. This larger torus extends beyond the orbit of Titan to the magnetosheath. Its source may be Titan's atmosphere.



The trajectories of Voyagers 1 and 2 are shown in relation to each other and to the inner Saturn system in this meridian plane plot. Voyager 2 passed about 5200 km closer to the planet. Dipolar magnetic field lines passing near the satellites are shown as dashed lines. These field lines correspond to the magnetic L-shells, associated with the satellites.

Eight of Saturn's small satellites are shown in this composite of Voyager 1 and 2 images. 1980S28, 1980S27, and 1980S26 are sometimes called the "shepherding" satellites as they appear to influence the F-Ring and the outer edge of the A-Ring. Just 50 kilometers separates the orbits of 1980S3 and 1980S1, the co-orbitals. 1980S13 and 1980S25, the Tethys trojans, occupy Lagrangian points near the satellite, as does 1980S6, the Dione trojan.



## Satellites

Winging its way into the Saturn system, Voyager 2 was geared to find small moons within the rings and near the larger satellites. Ground-based searches for such small moons had been fruitless, and so has been Voyager 2's photographic search. The cosmic ray instrument, however, may have detected a small moon sharing an orbit with Mimas, based on changes in the electron density in the satellite's wake.

Saturn's seventeen satellites fall into three main classes: giant Titan, seven intermediate-sized icy satellites, and eight small moonlets. Phoebe, Saturn's outermost satellite, may represent a fourth class: captured asteroids.

Voyager 2 flew closer to Enceladus, Tethys, Hyperion, Iapetus and Phoebe than did Voyager 1 last November, but was also able to study Mimas, Dione, Rhea, and Titan from greater distances.

Titan is shrouded by a thick atmosphere composed of about 82 percent nitrogen, topped by a multilayer haze. Neither Voyager 1 nor Voyager 2 was able to see below the clouds with their imaging cameras, but did obtain information on its size, temperature, and composition. It is slightly smaller than Jupiter's moon Ganymede, the largest moon in the solar system (both are larger than the planets Mercury and Pluto). Titan's surface temperature is about  $-290^{\circ}\text{F}$ . About six percent of the atmosphere is methane, which may act like water does on Earth — as vapor, liquid, and ice. The remaining 12 percent of the atmosphere may be argon, a colorless gas undetectable with spectroscopy, and traces of compounds of carbon, hydrogen, and nitrogen (including ethane, ethylene, and acetylene). Titan's atmosphere in the northern hemisphere appears darker than its southern hemisphere. A dark polar hood seen by Voyager 1 has changed and Voyager 2 photographed a dark polar collar.

Seven of Saturn's satellites are intermediate in size, as planetary satellites go, ranging in size from about 290 to 1530 kilometers (180 to 950 miles) in diameter. (Jupiter's satellites are either very much larger or very much smaller than these.)

Enceladus, seen at higher resolution (2 km) by Voyager 2 than by Voyager 1 shows evidence of a great deal of geological activity in its past. Its surface areas range from heavily cratered to smooth, indicating that some regions have been resurfaced. One possibility is volcanic activity, although on Enceladus these would be water volcanoes since the satellite is comprised mostly of ice. The volcanic theory is supported by the fact that the tenuous E-Ring, which spans more than 90,000 kilometers (60,000 miles) across space, is brightest near the orbit of Enceladus, suggesting that Enceladus may be a source of E-Ring particles. The appearance of the surface of Enceladus also seems to indicate crustal heating in the geologically recent past, possibly from tidal heating caused by interaction with Dione. It is such tidal heating that causes volcanoes on Io, Jupiter's sulfur-spewing satellite. It should be noted, however, that the orbit of Enceladus would have to have been much more elliptical in its past to provide sufficient tidal heating.

Tethys is grooved around nearly three-quarters of its circumference by a chasm several kilometers deep, one hundred kilometers wide, and 2000 kilometers long. The canyon, comparable in dimension to Mars's great Valles Marineris, may have resulted from the expansion of ice when Tethys cooled after its formation. Most of Tethys' surface is heavily cratered, indicating there has been no re-surfacing. One enormous crater is larger in diameter than the satellite Mimas.

Hyperion is highly irregular in shape — a disk-shaped object about 400 x 250 x 200 kilometers. Voyager 2's pictures, with a resolution of 10 kilometers, showed Hyperion to be battered and scarred with craters.

A great debate has arisen among planetary scientists concerning the nature of Iapetus. It has long been known that it has a dark side facing forward in its orbit around Saturn and a bright side facing backward. The dark hemisphere is as black as asphalt — one of the darkest surfaces in the solar system. Since there are no brighter areas on this region, such as might result from meteorites punching



through the black material to the icy crust and spraying out lighter-colored debris, the black coating must either be thick or constantly resupplied. Some scientists believe the black material comes from Iapetus' interior, while others believe it is external in origin — perhaps a coating of dust from Phoebe.

Phoebe, the last of Saturn's satellites to be observed by Voyager 2, is probably a captured asteroid.

Eight tiny moonlets also orbit Saturn. They appear to interact with the larger moons and to "control" the rings to some degree. 1980S28 orbits just outside the outer edge of the A-Ring. 1980S27 and 1980S26, the so-called "shepherd" satellites, flank the F-Ring, apparently herding it between them. 1980S3 and 1980S1, the "co-orbitals", share an orbit between the F- and G-Rings, playing a kind of cosmic leapfrog as they switch orbits in a four-year cycle. 1980S13 and 1980S25 share an orbit with Tethys, occupying mathematical points of stability (Lagrangian points)  $60^\circ$  ahead and behind the larger satellite. Similarly, 1980S6 orbits  $60^\circ$  ahead of Dione. Ground-based searches for other tiny moons at Lagrangian points of the other satellites have located none. However, a tiny moon is suspected to share the orbit of Mimas, based on data from the cosmic ray instrument.

For more information about the Voyager mission to Jupiter and Saturn, refer to the open literature, for both scientific and popular audiences. The following sets of articles represent official summaries of the mission and the results:

*Space Science Reviews*, Vol. 21, No. 2, November 1977.

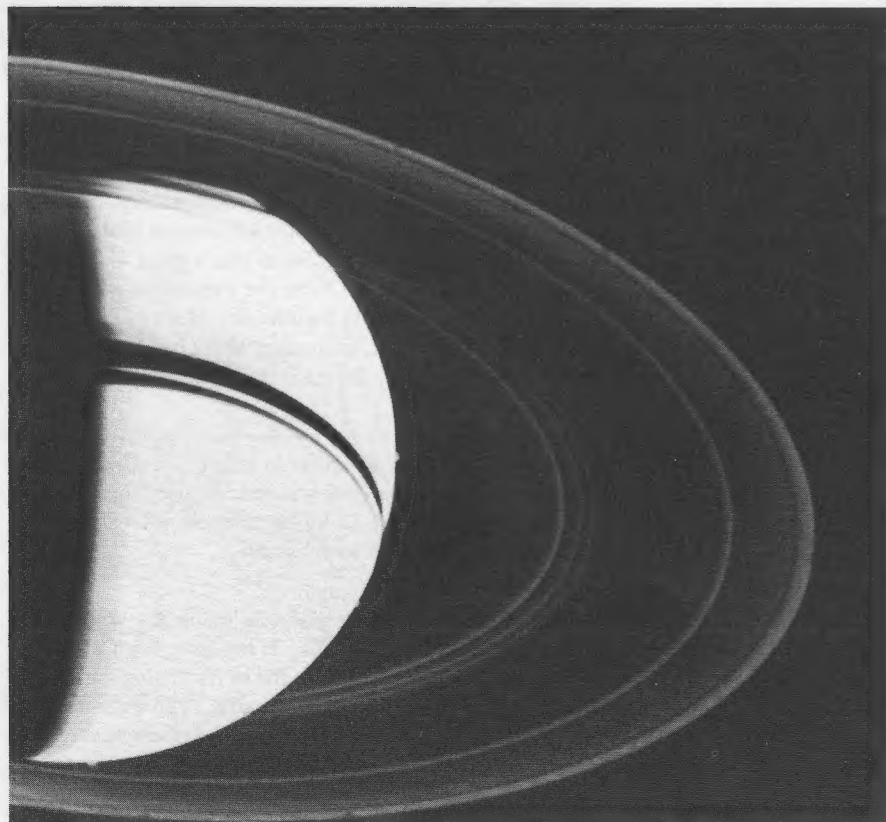
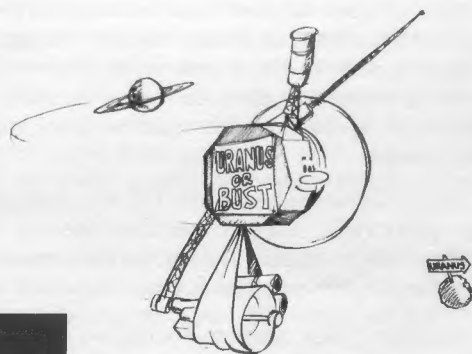
*Space Science Reviews*, Vol. 21, No. 3, December 1977.

*Science*, Vol. 204, June 1, 1979, pp. 945-1008, 913-921 (Voyager 1 Jupiter results).

*Science*, Vol. 206, November 23, 1979, pp. 925-996 (Voyager 2 Jupiter results).

*Science*, Vol. 212, April 10, 1981, pp. 159-243 (Voyager 1 Saturn results).

*Science* (planned publication date January 1982) (Voyager 2 Saturn results).



This was one of the first pictures obtained once Voyager 2 resumed returning images on August 28 after its scan platform was commanded to point to Saturn again. Problems with the platform, on which Voyager's cameras and three other instruments are mounted, had prevented the return of images for several days after closest approach to the planet on August 25. Out-bound observations were of the southern hemisphere and the unlit side of the rings. Voyager 2 crossed the ring plane only once, dipping below it about 1200 kilometers (750 miles) outside the G-Ring shortly after closest approach to the planet. This view shows some detail and differences in the complex ring system. The "reddening" of the B-Ring on the unlit side also was seen in Voyager 1 images. The shadow of the rings falls across the planet's equator in this view. 3.4 million kilometers (2.1 million miles)